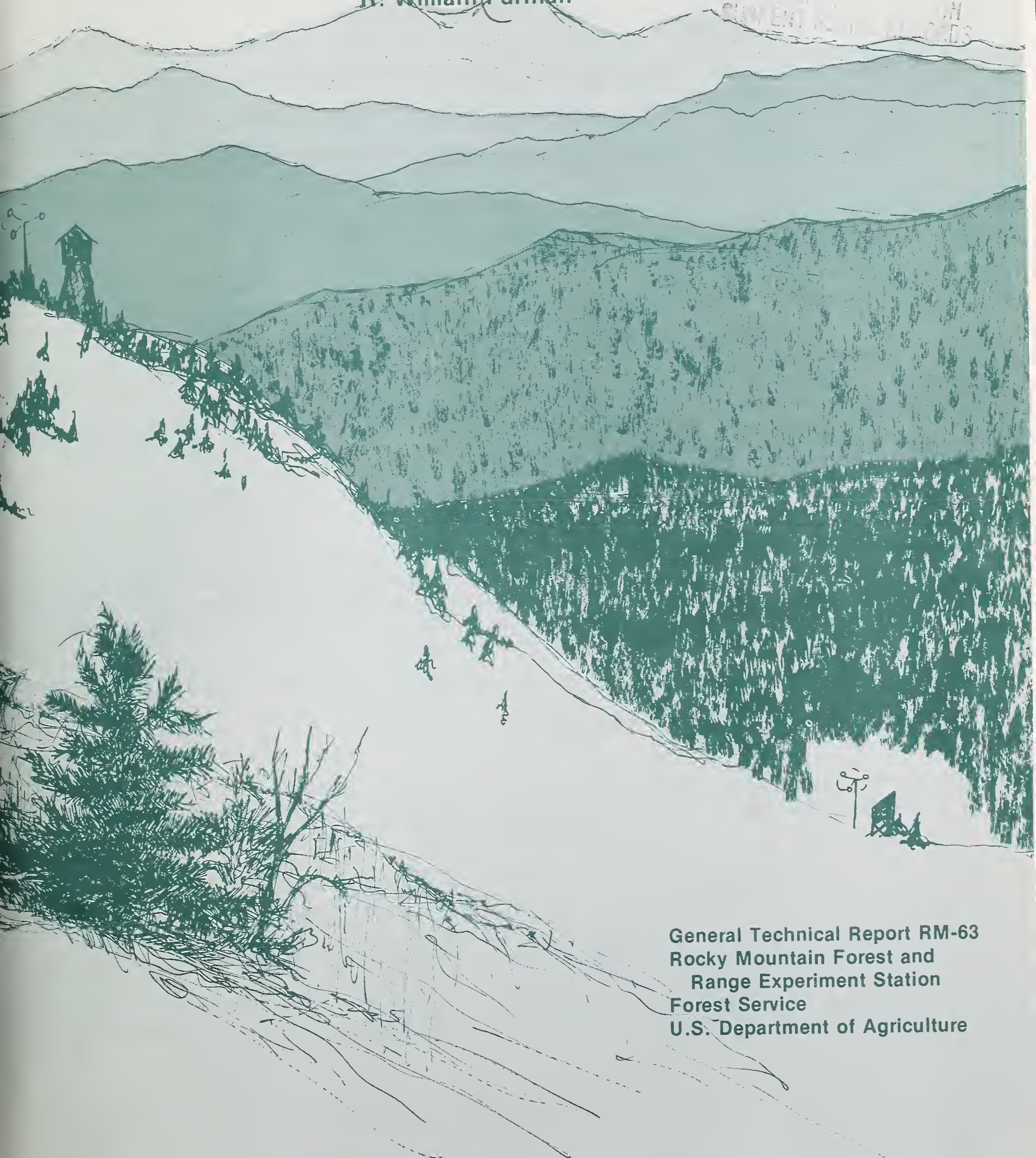
Using Fire Weather Data in Prescribed Fire Planning: Two Computer Programs

R. William Furman



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Abstract

Local fire managers can use previous years' fire weather observations (including data from the National Fire Weather Library) to estimate probabilities of future days' falling within burning and smoke dispersal prescriptions. The computer programs can be used by field personnel from remote terminals via telephone service.

Keywords: Prescribed fire, fire use planning, climatology, computer program.

[1] *Central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

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MANAGEMENT IMPLICATIONS

Although fire behavior and fire danger are to a large part determined by the past and present weather, fire use planners have often lacked access to or failed to use climatological information as a planning tool. The current emphasis on more professional fire management policy will produce increased use of climatological information in future fire use planning.

A prognosis of what the weather may be 6 months to a year in the future can be obtained by determining the frequency with which events happened in the past. Historic weather records reveal patterns which can be used by fire planners to designate preferred seasons for prescribed burning and to help establish a reasonable target for a burning program.

INTRODUCTION

How many days a year can be expected to satisfy the prescribed weather conditions for a specific planned burning operation?

During what parts of the year are favorable prescribed burning conditions most likely to occur?

Do favorable burning days occur together in groups of 2, 3, or more contiguous days or are single occurrences of burning days more likely?

What amount of persistence is characteristic of the weather conditions in a region? In other words, if today is a burning day, what are the chances that tomorrow will be one?

How will the expected number of burning days per year be affected if smoke management restrictions are added to the prescription?

The planner may reasonably ask these questions in trying to find the best method for using fire to accomplish specific objectives. Reliable answers to these questions enable the planner to reduce the uncertainty of predicting the occurrence of the number of days meeting his fire prescription. The planner may base the choice of method on the conditions expected. For example, if one can expect 30 days a year acceptable for slash disposal, then the plan may be to dispose of 1/30 of the total amount of slash on each disposal day. That way the desired outcome of disposing all the slash will, in the long run, be achieved.

In the normal course of planning, fire management must be concerned with weather as much as a year or more in the future. However, the state of our technology does not permit an accurate weather forecast much beyond 3 days. Another source of future weather information must be used—climatology. Climatology substitutes weather hindsight for weather foresight by assuming climate in the near future will be similar to the climate of the recent past, say in the past 2 or 3 decades. We cannot determine which specific weather occurrences from the past will be repeated at any given time in the future. Instead, we examine all of the past occurrences and assume they will occur with the same frequency in the future. For example, if our data sample is large enough we may reasonably expect half of the future years will experience more days in prescription than the median number of prescription days per year experienced during the past years.

WEATHER INPUTS TO FIRE USE PLANNING

Two items are basic to a climatology of prescribed weather conditions—a weather data base and a prescription.

Data Base

The data base most fire managers will be using is the fire weather records obtained from the fire weather stations in their management unit. Fire weather data are taken for and used in assessing daily fire danger on a protection unit. They may be

observations taken by the fire management agencies for the explicit purpose of determining fire danger, or they may be taken by the National Weather Service and used by the fire managers.

Typically in a fire weather observation, the measured variables include state of the weather, dry bulb temperature, relative humidity, windspeed and direction, moisture of 1/2-inch pine dowel array (fuel sticks), precipitation, and sometimes maximum and minimum temperatures and humidities. These data are normally accessible through the National Fire Weather Data Library (Gen. Tech. Rep. RM-19, Furman and Brink 1975). This data library is a user-oriented data management system established on the USDA computer system in Fort Collins, Colo. From remote terminals via telephone service, users may create their own data file of selected information using available software. This data library is kept up to date with the observations used to compute daily fire danger across the nation.

Prescription

The prescription is a translation of the fire manager's treatment objectives, such as scorch height and flame length, into weather and fuel conditions that will allow those objectives to be achieved. It is a set of conditions which must be satisfied before a decision should be made to execute a burn treatment. It is also used to define the environment for the proper fire to accomplish the treatment objectives. Specificially, it should consist of the minimum number of weather and weather-related variables necessary to restrict the fire behavior to the desired characteristics. All the conditions in a prescription must occur simultaneously for a prescription to be satisfied.

Using either too restrictive a prescription or an overly complex one is undesirable. Either will result in a decrease in the number of days predicted to be acceptable for burning. For example, requiring the 10-hour timelag fuel moisture to be 13-15% instead of 10-15% will severely restrict the number of acceptable days. Similarly, if a prescription is too complex, that is, if there are many more viariables than necessary, the chance of satisfying all the variables simultaneously is small. Fire managers should take a critical, professional look at their prescriptions and eliminate the variables that are only marginally applicable. This will increase the number of days available for using prescribed fire.

When the manager wants to limit burning to days meeting specific smoke dispersal patterns, an additional, specialized set of variables becomes part of the prescription. The dispersal of smoke depends upon the stability of the air layer above the smoke source and on the wind speed and direction in that layer. Therefore, estimation of smoke dispersion characteristics depends on measurements of properties in the layer of atmosphere above the area to be burned. These measurements are, of course, never actually taken. However, measurements from particularly situated fire weather stations can permit crude approximations of the data which would have been taken. For example, data from two fire-weather stations, one at a high elevation site (e.g., a lookout), the other at a low elevation site not too far from the high site (i.e., 30 to 40 miles), can be combined to obtain crude estimates of smoke dispersion characteristics.

Three properties of the air layer next to the earth surface strongly regulate the ability of the smoke column to rise an acceptable distance above the source and be carried away in a desirable direction—transport wind direction, transport windspeed, and atmospheric stability or instability.

Transport Wind Direction

It is reasonable to assume the wind direction at a well exposed lookout is representative of the wind direction in the nearby free atmosphere (Judson 1965) at that altitude. At any given instance this may not be true, but in the long run we can expect this assumption to hold within limits of $\pm 22.5°$. The lookout wind direction can thus be used as an indicator of the direction smoke will be transported. For most planning purposes no greater precision is needed.

Transport Windspeed

Finklin[2] reported a positive correlation between the afternoon windspeed at a mountaintop station and windspeed in the free atmosphere. Judson (1965) also reported a positive correlation between windspeed at a high elevation station and windspeed at the same altitude in the free atmosphere over Weather Service stations roughly 100 air miles away. The high elevation station windspeed consistently underestimated the free air speed. Thus, any error in using lookout windspeed to estimate smoke dispersion conditions aloft will probably be on the safe side.

[2] *Finklin, Arnold I. 1977. Climate of the Selway-Bitterroot Wilderness. Office Report for Fire in Multiple Use Management Development and Application Program, USDA For. Serv., Intermt. For. and Range Exp. Stn., North. For. Fire Lab., Missoula, Mont. 260 p.*

Atmospheric Stability

The third property of air important in predicting smoke dispersal is atmospheric stability; the resistance of the atmosphere to vertical motion. The smoke-laden air from a fire will continue to rise through the surrounding air only as long as it is warmer than that air. If the air above the fire site is warmer than the rising smoke-laden air from the fire, the smoke will not rise; instead, it will sink to the valley floor. Schroeder and Buck (1970) contains a detailed and highly readable discussion of this property.

The tendency of the warm, smoke-laden air from a fire to rise through the air above the fire site can be determined by comparing the rate of cooling of the rising air to the changes in temperature in the air at increasing elevations above the fire site.

The change in temperature per 1,000 feet elevation of the air in a column over a point on the earth's surface is called the atmospheric lapse rate. To approximate this rate, divide the difference in temperature between the air at a high elevation station (e.g., a lookout) and the air at a neighboring low elevation station (e.g., one in a valley bottom), by the thousands of feet difference in elevation between the two sites (fig. 1, solid line).

The cooling of rising air is expressed as a theoretical constant rate: a parcel of air mechanically lifted and not allowed to mix with the surrounding atmosphere would cool, because of expansion, at a fixed rate of 5.4° F/1,000 feet of elevation as long as it remained unsaturated (fig. 1, dashed line). This rate is called the dry-adiabatic lapse rate.

If we subtract the dry-adiabatic lapse rate (5.4° F/1,000 ft.) from the atmospheric lapse rate (valley bottom temperature minus lookout temperature/1,000 ft.) and get a positive number, we will have good smoke dispersion. The bigger the difference, the better the dispersion. A negative difference means poor smoke dispersal conditions.

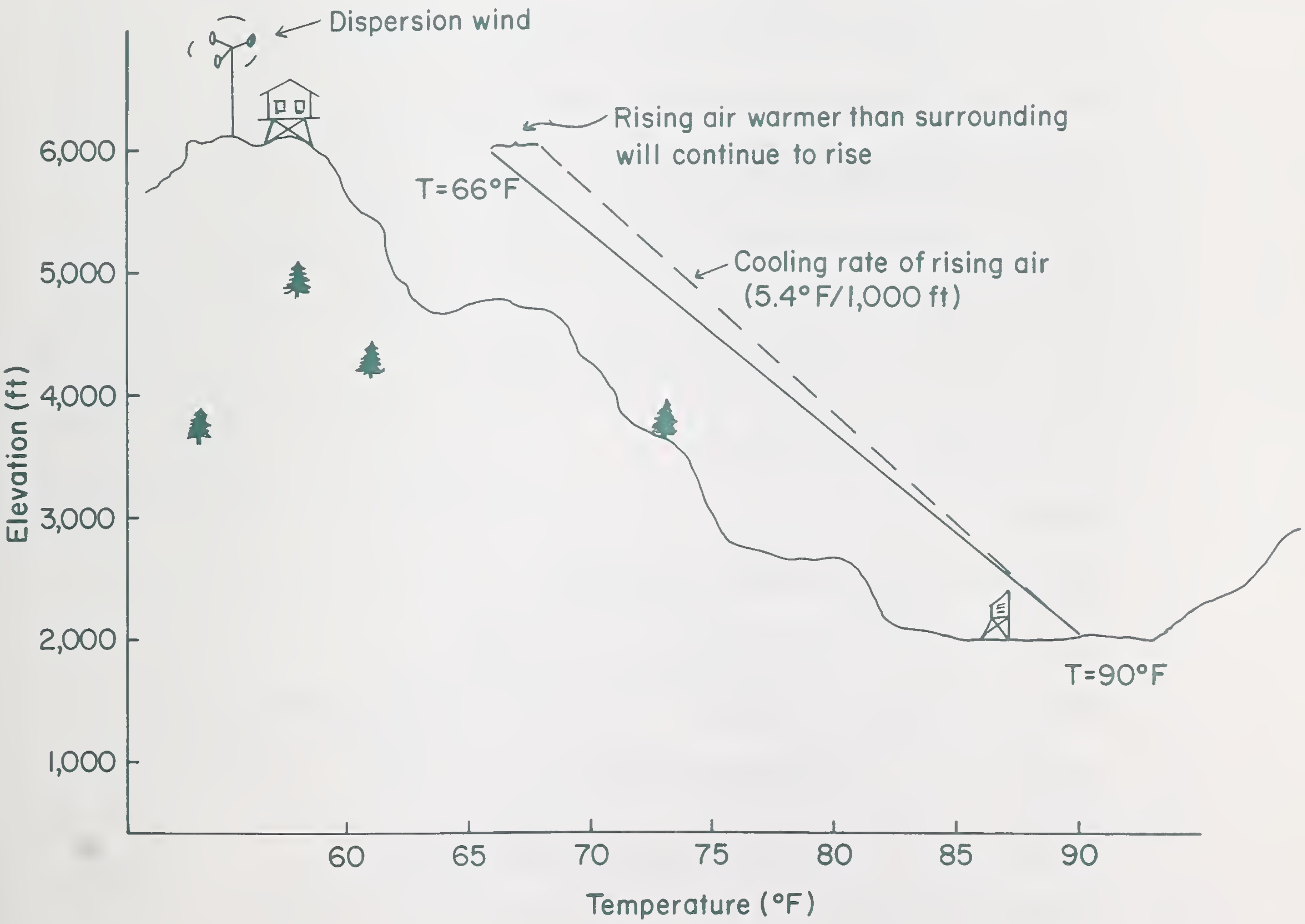

Figure 1.—A schematic of the atmospheric (solid) and adiabatic (dashed) lapse rates between high and low elevation stations.

COMPUTER PROGRAMS FOR FIRE PLANNING CLIMATOLOGY

Two computer programs have been developed and saved on the USDA computer at Fort Collins, Colo., as an aid to fire managers. These programs can be used separately or together to analyze pertinent weather data.

PRESCRB—A Climatology for Fire Use Planning

The computer program PRESCRB synthesizes weather data into a meaningful form for fire use planning. Program input includes a data base of meteorological observations and the user's burning season and prescription. The data base can be provided by the user or can be obtained from the National Fire Weather Data Library. The program counts the occurrences of days which had weather conditions satisfying all of the prescription variables and presents this information on the output in various formats.

Instructions to Execute PRESCRB

The runstream (a list of computer commands) in figure 2 provides the information necessary to build a data file of weather records from the National Fire Weather Data Library and execute PRESCRB. The flexibility of the program allows users to use meteorological data files other than the National Fire Weather Data Library (i.e., the output data file from program FIRDAT or any other set of data). Users not desiring to build the data-file can eliminate instructions 1 through 7. Executing this runstream will produce the output in figure 3.

An explanation of figure 2 is as follows:

1. Obtain exclusive use of the library program file.
2. Assign the *first* of the data files (tapes) from which the data are to be extracted. If more than one file is needed, they will be dynamically assigned and freed during execution. See Gen. Tech. Rep. RM-19 for instructions on how to obtain the current list of data files.

```
     1234567890123456789012345678901234567890

 1.  @ASG,AX FIREDATALIB*PRØGRAMS.

 2.  @ASG,A FIREDATALIB*45A-47.

 3.  @USE 2.,FIREDATALIB*45A-47.

 4.  @ASG,T 15.

 5.  @XQT FIREDATALIB*PRØGRAMS.GETDATA2

 6.    45250800  45250899

 7.  @FREE 2.

 8.  @ASG,AX CLIMATØLØGY*PRØGRAMS.

 9.  @XQT CLIMATØLØGY*PRØGRAMS.PRESCRB

10.  STATN 452508  2600  2   540501 771031 ØUTBACK RS

11.  VARIBL  4  5 15WIND SPEED

12.  VARIBL  5  5 1510-HR FUEL MØISTURE

13.  @FIN
```

Figure 2.—Example runstream for obtaining output from program PRESCRB.

PRESCRIPTION CLIMATOLOGY

A B C

STATION NO. 452508 ELEV. 2800 FT OUTBACK RS

PRESCRIPTION VARIABLE(S)	LIMITS FROM	TO
D WIND SPEED	5 -	15
10-HR FUEL MOISTURE	5 -	15

SEASON E F
BEGAN MAY 1 - ENDED OCT 30 FOR THE YEARS 1954-1977

G NO. OF YEARS OF GOOD DATA FOUND 24

QUARTILES

NO. OF BURNING DAYS ENCOUNTERED IN AT LEAST	PERCENTAGE OF YEARS
H 44	75%
I 51	50% - MEDIAN ESTIMATE
60	25%

J CONFIDENCE LIMITS ON MEDIAN ESTIMATE
THERE IS A 85 PERCENT CHANCE THE TRUE MEDIAN LIES BETWEEN 46 AND 52 BURNING DAYS PER YEAR.

****

ANNUAL MARCH OF BURN DAYS BY 10-DAY PERIODS

K DATES	TOTAL NO. OF DAYS	NO. OF BURN DAYS	AVG NO. BURN DAYS
5/ 1- 5/10	167	34	2.0
5/11- 5/20	172	57	3.3
5/21- 5/30	191	49	2.6
6/ 1- 6/10	184	45	2.4
6/11- 6/20	205	44	2.1
6/21- 6/30	223	112	5.0
7/ 1- 7/10	229	121	5.3
7/11- 7/20	235	107	4.6
7/21- 7/30	260	74	2.8
8/ 1- 8/10	237	53	2.2
8/11- 8/20	234	43	1.8
8/21- 8/30	259	81	3.1
9/ 1- 9/10	240	72	3.0
9/11- 9/20	226	89	3.9
9/21- 9/30	224	82	3.7
10/ 1-10/10	173	79	4.6
10/11-10/20	133	64	4.8
10/21-10/30	108	45	-.0
	-----	-----	
TOTALS	3700	1251	

PERCENTAGE OF TOTAL DAYS WHICH OCCURRED IN
PRESCRIPTION = 33.8

****

****

LENGTH OF BURNING PERIODS - FREQUENCY TABLE

L LENGTH OF PERIOD (DAYS)	NO. OF OCCURRENCES (COUNT)	PERCENT OF TOTAL NO. OF PERIODS	CUMULATIVE PERCENT
1	337	53.	53.
2	142	23.	76.
3	71	11.	87.
4	42	7.	94.
5	16	3.	96.
6	12	2.	98.
7	5	1.	99.
8	2	0.	99.
9	1	0.	100.
10	1	0.	100.
11	1	0.	100.
12	0	0.	100.
13	0	0.	100.
14	0	0.	100.
15	0	0.	100.
16	1	0.	100.

****

M OBSERVED COUNTS AND PROBABILITIES OF TOMORROWS CONDITIONS KNOWING TODAYS

		TOMORROW NB	TOMORROW B	
TODAY	NB[1]	1771(.75)	585(.25)	2356
	B[2]	582(.48)	620(.52)	1202

1 Non-burn day

2 Burn day

****

Figure 3.—Output from program PRESCRB—a prescription climatology for a fictitious fire weather station, with inputs (A,B,C,D) and outputs (E,F,G,H,I,J,K,L,M).

3. Assign internal unit number 2 to the library data tape.
4. Assign a mass storage file to receive the card images. This is a temporary file and will disappear when the run terminates.
5. Execute the absolute element to select the data and write it on file 15.
6. Data cards specifying the beginning and ending station-year of the data cards to be extracted.
7. Release fire weather library data files.
8. Obtain exclusive use of the program file which includes PRESCRB.
9. Execute the absolute element to produce a prescription climatology. Input weather data is expected on file 15.

10., 11., and 12. Control data cards for PRESCRB.

13. Terminate run.

If it is known before the first execution that the program PRESCRB will be executed several times using the same weather records, weather data should be saved in a file on the first run to save the cost of recreating that file on subsequent runs. This may be done by substituting the following for instruction number 4:

4. @ ASG,UP CARDS.
4a. @ USE 15., CARDS.

Then on subsequent runs, eliminate instructions 1-7 and substitute the following two instructions:

1. @ ASG,AX CARDS.
2. @ USE, 15., CARDS.

Depending on current facility policy, a file saved as above will be saved on the computer for a number of days, 6 days at this writing. To prevent being charged for saving a large data file on mass storage beyond its useful period, insert the following two instructions in front of the @ FIN card on the last execution of the program with that data set:

@FREE 15.
@DELETE CARDS.

Program Input

Input required for execution of PRESCRB is of two kinds, program data and weather data. The program data consists of a card on which is designated the fire weather station whose weather data is to be analyzed, the number of variables in the prescription, and the dates defining the season to be analyzed. The remaining cards in the program data deck are cards which define the variables and their limits as they make up the prescription. The weather data can be analyzed over and over again by repeating the program data deck. Following is a detailed description of the program data cards:

First data card—STATN—one card

Col. 1-5	STATN
Col. 7-12	Station number
Col. 14-18	Station elevation (right justified)
Col. 20-21	Number of variables in prescription—maximum of 10 (8 if relative humidity is used)
Col. 23	Number of variable format cards
Col. 25-26	First year of meteorological data to be analyzed
Col. 27-30	Beginning month and day of desired burning season
Col. 32-33	Last year of meteorological data to be analyzed
Col. 34-37	Ending month and day of desired burning season
Col. 39-80	Identifying information

Data cards—VARIBL—one card for each variable in prescription

Col. 1-6 VARIBL

Col. 8-9 Variable number from list below:

1. Drybulb temperature (°F)
2. Relative humidity (%) (for data sets other than Fire Weather Data Library, assign relative humidity to "other variable.")
3. Wind direction (numbers representing 8 cardinal points. Ex: NE = 1, E = 2, . . .)

   Note: For wind direction prescription limits which bracket north, enter the larger direction number as the lower limit in columns 10-12 and the smaller direction number in columns 13-15. Ex: Col. 12 = 7 and col. 15 = 1. This will set an acceptable range of wind directions from and including NW through and including NE.
4. Wind speed (mph)
5. 10-hour fuel moisture (%)
6. Maximum temperature (° F)
7. Minimum temperature (° F)
8. Maximum relative humidity (%)
9. Minimum relative humidity (%)
10. Precipitation amount (inches, tenths, and hundredths; no decimal)
11. Do not use
12. Other variables
13. Other variables
14. Other variables

Col. 10-12	Lower limit of prescription variable (right justify, units specified above)
Col. 13-15	Upper limit of prescription variable (right justify, units specified above)
Col. 16-45	Name of variable

Unless otherwise specified with a FORMAT card, the format used in the Fire Weather Data Library will be assigned. A FORMAT card is needed if items 12 and higher are used. The format must be

compatible with variable list—Station no., year, month, day, N(1), N(2). . .N(10) where the N's are integer variables.

Data card—variable format card (optional)

Col. 1-6	FORMAT
Col. 7-78	Conversion specifications Note: if relative humidity is being used without temp from Fire Weather Data Library tapes and if a variable format card is required allow for temp and moisture index to be read in as next to last and last variables (i.e., format should end with T14,I3,T61,I1).

The program PRESCRB is expecting the input weather data to be on file 15. The previous runstream took care of this. If the user is using data from a source other than the National Fire Weather Data Library, the requirements are that the data file consist of single card records and be assigned to file 15. Further requirements are detailed under the variable format data cards.

Program Output

The output from PRESCRB includes the following:

Station.—The first line of the output displays the number of the station (fig. 3A) for which the analysis was performed, the elevation of the station (fig. 3B), and some identifying information such as the name of the station (fig. 3C). This information is provided by the user.

Prescription.—The ranges of the variables selected by the user to define the prescription are listed (fig. 3D).

Season.—The season (fig. 3E) and years (fig. 3F) of the weather data which are included in the analysis are shown after the prescription. The dates of the desired season are provided by the user.

Quartiles.—Quartiles are determined by counting the number of burn days, i.e., the days on which all conditions in the prescription are satisfied, in each year, ranking the counts in ascending order, and selecting the count after one-fourth, one-half, and three-fourths of the years. Hence, in the long run, 75% of the years will have at least as many days suitable for burning as the smaller number (fig. 3H), and only 25% of the years will have more burning days than the larger number. The 50-50 point or the median is the middle number (fig. 3I). Fifty percent of the years will have more than the median and 50% will have less.

Confidence limits on median.—The quartiles are estimates of the true values. That is, the data available are used to estimate the true quartile values. The more data available, the better the estimates. The amount of error which may be involved in estimating the median is determined first by finding the sample values on both sides of the median which contain the 90% confidence limits on the median. Then the probability that the true median will fall between those sample values is computed. Hence, in the sample (fig. 3J) it was determined that there is a probability of 85% that the true median falls between the sample values of 46 and 52 burning days per year. This information is a clue to the credibility of the median estimate. A probability level ≤90% coupled with confidence limits wide enough to include the quartile values is indicative of a data sample too small to contain enough information to provide a good estimate. A planner can have more faith in the numbers he works with if he knows how much uncertainty is associated with those numbers.

Annual march of burn days.—An important piece of planning information is how the burn days are distributed through the season. This is presented as the average number of burn days in successive 10-day periods (fig. 3K). (Note: A value of −0.0 indicates there were insufficient data to calculate an acceptable average value.) These can be plotted on a piece of graph paper to show the portion of the season which favors the occurrence of burning days. For those months with 31 days, the extra day is included without comment in the 21-30 group. That explains why for July 21-30 and August 21-30 in figure 3 it was possible to accumulate 260 and 259 days from only 24 years of data (fig. 3G).

If, as a result of the information, it is decided to concentrate the burning efforts during a certain period of the season, it would then be wise to rerun the PRESCRB program specifying this new season to get a more accurate estimate of the burning day quartiles.

Length of burning periods.—Because of vagaries in the climate, burning days may occur singly or in pairs, or may occur typically in longer periods of, say, 4 or 5 days. To determine this information the program keeps a count of the number of days in each burning period (fig. 3L). A burning period is a single day or consecutive days preceded and followed by no-burn days. The count of the number of burning periods of exactly n days long which were encountered in the data is displayed as a tabulation of period lengths.

The purpose of these numbers is to help the manager form an objective picture of how the burning days are dispersed through the season. They

could occur mostly in single days, or in pairs of days, or if there is a strong seasonal component, long strings of burning days could occur. The information obtained from this method of displaying the data should be useful in planning a burning schedule.

Observed counts and probabilities of tomorrow's conditions.—Often as sensory observers of the weather we formulate erroneous impressions of how persistent or constant our weather is. We are often under the impression that in the summer one nice day follows another. Because of all the conditions which must be satisifed simultaneously, there is little assurance that one burn day will follow another. It is easy to determine just how often a burn day may be expected to follow a burn day or a no-burn day to follow a no-burn day. There are only four possible combinations of burn, no-burn days in two consecutive days:

1. burn day followed by a burn day
2. burn day followed by a no-burn day
3. no-burn day followed by a burn day
4. no-burn day followed by a no-burn day

By counting the number of times each of these combinations occurs in our data sample we can determine the percentage of time that each of the four combinations may be expected to occur (fig. 3M). In essence what we are determining is how much information about conditions tomorrow is available from conditions existing today.

The total number of occurrences in this table of conditional probabilities is the total number of pairs of consecutive days encountered. This number will be different than the total number of days because of the breaks in the continuity of the weather record.

MERG3—A Computer Program to Extract Smoke Management Information from Fire Weather Data

The computer program MERG3 has been developed to obtain for fire planners the three smoke dispersion variables discussed earlier (transport windspeed and direction and atmospheric instability) for use in the planning program PRESCRB. When it is desirable to consider the number of days that can be expected with both favorable burning conditions and favorable smoke dispersion conditions, the recommended procedure is to include in the prescription variables and limits which define acceptable smoke dispersion conditions. For example, a good dispersion day will have a transport windspeed (lookout windspeed) sufficient to move the smoke away from the area and atmospheric instability which will allow the smoke column to obtain sufficient height so it can be dispersed aloft and not near the ground.

The data for such an analysis can be obtained from the simultaneous fire weather observations from a high elevation station such as a lookout and a low elevation station not more than 40 air miles away. The windspeed and direction at the lookout will provide an approximation to the transport windspeed and direction. The temperature difference between the two stations can be used to estimate the free-air (atmosphere) lapse rate which can be compared to the dry-adiabatic lapse rate. For each day that weather data are available for all of the stations (high, low, and base) MERG3 computes the difference between atmospheric and adiabatic lapse rates between a high and low station and adds this information along with the high station windspeed and direction to the end of the weather record from the base station used in the planning analysis. MERG3, in fact, writes a data file with the modified weather records which can be used directly by program PRESCRB.

Instructions to Execute MERG3

The runstream shown in figure 4 will execute MERG3 and produce an output from PRESCRB.

Instructions 1-9 in figure 4 cause a data file to be created on file 15. This file consists of the weather records from the high elevation station, the low elevation station, and the base station if it is different from the previous two.

Instructions 10-18 cause execution of program MERG3 which expects input card images on file 15 and will output card images on file 14, and uses temporary files 11 and 12. Since program PRESCRB is expecting input card images on file 15, the contents of file 14 should be copied to file 15 as in instruction 18.

Instructions 19-25 cause program PRESCRB to be executed on this newly created data set.

Instructions 1-18 must be executed for each different data set created.

Program Input

As in PRESCRB, MERG3 expects two input files: a card image file with data for program execution and a file of meteorological data. The data cards for program execution define a weather station at a low elevation site, one at a high elevation site, and optionally, a base station site which may include either of the previous stations. The base station is the weather station which will be used to represent the activity site. These data cards should be ordered by station number with the lowest station number first.

```
1234567890123456789012345678901234567890123456789012345678901234567890

@RUN
@ASG,AX FIREDATALIB*PRØGRAMS.
@ASG,A FIREDATALIB*45A-47.
@USE 2.,FIREDATALIB*45A-47.
@ASG,T 15.
@XQT FIREDATALIB*PRØGRAMS.GETDATA2
  45201270  45201277
  45250870  45250877
@FREE 2.
@ASG,T 11.
@ASG,T 12.
@ASG,T 14.
@ASG,AX CLIMATØLØGY*PRØGRAMS.
@XQT CLIMATØLØGY*PRØGRAMS.MERG3
452012 6000HIGH
452508 2800LOW
452508 2800BASE
@CØPY 14.,15.
@XQT CLIMATØLØGY*PRØGRAMS.PRESCRB
STATN 452508  2800  4 1 700601 770930 ØUTBACK RS - WAYUP LØ
VARIBL  4  5 15WIND SPEED
VARIBL  5  5 1510-HR FUEL MØISTURE
VARIBL 12 -2 99DEGREES INSTABILITY
VARIBL 13  5 50LØØKØUT WIND SPEED
FØRMAT(I6,3I2,T29,I3,T33,I3,T72,I3,T78,I3)
@FIN
```

Figure 4.—Example runstream for executing program MERG3 to prepare a data set, then analyzing that data set using program PRESCRB.

The weather data file consists of weather records from the National Fire Weather Data Library for the two or three stations specified in the program data deck. The records should be on the file in increasing order by station number then by date.

A detailed description of MERG3 program data cards follows:

Station Cards—One data card is required for each station, low, high, and base (lowest station number first)

Col. 1-6 Station number

Col. 7-11 Station elevation (right justified)

Col. 12-15 Relative location identifier—either "high," "low," or "base" (left justified). If the base station is the same as either the "high" or "low" station then the duplicate station number should be the last card.

Program Output

The output from the execution of MERG3 will be (a) one line on the printer, and (b) card images altered by the additional information written on file 14. An example of the one line of output on the printer is:

499 RECORDS WERE WRITTEN ON FILE 14.

The card images of weather data will be written on file 14 in the following format:

Col. 1-66	Base station input data in the same format as read in
Col. 72-74	Difference between computed lapse rate and adiabatic lapse rate (5.4° F). (I3)
Col. 75-77	Wind direction from high station (I3)
Col. 78-80	Wind speed from high station (I3)

An end-of-file is written after the last record.

AN APPLICATION TO PRESCRIBED BURNING PLANNING

The following narrative demonstrates how climatological data are used through PRESCRB and MERG3 in a hypothetical fire use planning problem.

Suppose the Fire Management Officer of the Outback Ranger Station, Utopia National Forest, needs to treat with fire 100,000 acres of ponderosa pine every 10 years for fire reduction purposes. The long range planning problem is determining the resources needed to achieve the 10-year goal of burning 100,000 acres in this fuel type. The medium range planning problem is how to burn an average of 10,000 acres each fiscal year.

Effective planning requires the FMO know how many acres must be burned each day when weather and fuel moisture meet prescription, given the number and distribution of good burn days expected during the planning period. If the minimum number of acres needed to be burned each day is large, crew and equipment needs will be high, and missing an opportunity to burn even 1 day will result in a large backlog. If the minimum acreage is low, the FMO can trade off increases in crew and equipment against decreases in the number of days required to do the job.

The FMO uses the output from PRESCRB shown in figure 3 for planning. Recall that the yearly target for prescribed burn acreage is 10,000 acres. The filed weather data indicates there is a 50-50 chance each year will have at least 51 days suitable for burning (fig. 3I). Assuming all the days are correctly forecasted and are utilized for burning, the rate of burning must be 10,000/51 = 196 acres on each burn day. However, there is only a 50-50 chance there will be 51 days for burning. If the 50-50 odds are not good enough, then the last quartile indicates there is a 75% chance at least 44 burning days will occur (fig. 3H). Roughly this means that the burn quota for each of those burn days is 10,000/44, or approximately 227 acres. The per acre cost of burning 227 acres per day versus 196 acres per day may be higher; however, the chance of accomplishing the yearly objective of 10,000 acres prescription burned is much better if more acres are burned each day.

A planner desiring to use the median estimate should also desire to know the quality of that estimate. With 24 years of data (fig. 3G), one may surmise that the median estimate is very close to the true value, which is confirmed by the confidence limits on the median estimate. The 85% envelope lies between 46 and 52 days per day (fig. 3J), that is well within the outer quartiles.

Figure 5 is a plot of a three point running mean of the seasonal march of average burning days (fig. 3K). When the information is displayed in this fashion it is easy to see that burning days are more likely to occur early in the summer. This information can be used to plan a burning program in which the burning effort will be concentrated in the part of the season when chances of having good burning weather are best.

From figure 5 the best chance of encountering good burning weather is during the period June 11 to July 20. The recommended procedure now is to specify this specific period as the season and rerun PRESCRB. The output will provide a much better estimate of the number of burning days which can be expected during this selected 40-day period.

Looking at the distribution of burning period lengths (fig. 3L) we see that 53% of the burning periods occurred as a single burn day sandwiched between no-burn days. Twenty-three percent of the burning episodes occurred in 2-day stretches. Indications here are that since 76% of the burning periods occurred as 1- or 2-day episodes, the fire manager will have to rely heavily on the fire weather forecaster for advanced notice of burning weather and not count on long periods of weather favorable for burning.

The conditional probabilities in the box at the bottom of figure 3 show that in the data sample, 1,771 instances were found where a no-burn day followed a no-burn day and only 585 cases where a burn day followed a no-burn day. If today is not suitable for burning, there is about a 75% chance that tomorrow will not be a good day either. If today is a burn day, considering the whole season, chances are nearly 5,050 the same conditions will persist through tomorrow. For any specific time of the season these probabilities will change and the fire weather forecaster should be able to modify those probabilities for a given time of the year and specific location.

If the FMO also has smoke dispersion objectives, he must determine whether sufficient data are available for such an analysis. An inspection of the fire weather stations in the Outback Ranger Station area reveals a lookout about 35 air miles away and about 3500 feet higher in elevation. The data from this station, when used in conjunction with the data from Outback Ranger Station, should be adequate to estimate the atmospheric instability and provide estimates of transport level windspeed and direction.

Because of the smoke management considerations, the prescription is enlarged to include two smoke dispersion variables. In our new prescription we want to include only those days which in addition to acceptable fuel moisture and surface wind condition have atmospheric instability and transport windspeed conducive to good smoke dispersion. To limit an acceptable burning day to one with favorable vertical transport conditions, a

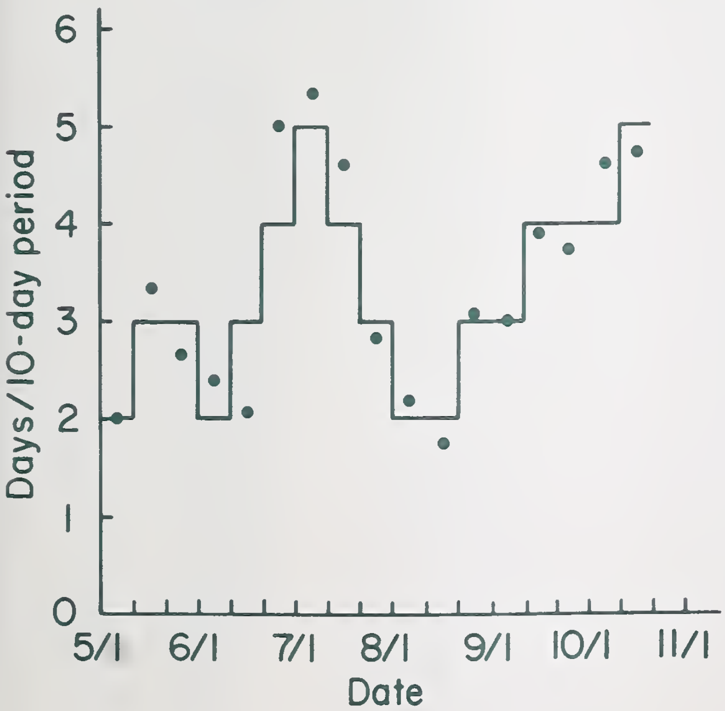

Figure 5.—A plot of the seasonal march of burning days from figure 1 (dots are 10-day averages; solid lines are 30-day running averages rounded to nearest whole day).

prescription variable was included which imposed an acceptable range on the atmospheric instability of -1 to 99. Positive numbers correspond to favorable instability, and negative numbers indicate stability (negative instability). In setting this prescription, the lower limit (-1) was set because it was reasoned heat from the fire would provide enough buoyancy to overcome a small amount of negative instability. This reasoning may not hold true for fires of low intensity, in which case the prescription limits should be adjusted accordingly. The transport windspeed (lookout windspeed) was considered to be acceptable if greater than 10 mph. Now MERG3 and PRESCRB are run with the new prescription using the runstream in figure 4. Only half the years have 11 days meeting the new prescription with the smoke management constraints. The 25% and 75% limits are 12 and 10 days per year. Similar reductions in numbers of burn days expected occur when additional variables are added to a prescription. The reduced number of burning days for the new example prescription is the result of both a shortened observation season at the lookout and the stricter prescription.

SUMMARY

The use of the probabilistic information in this analysis is mostly subjective. For long range planning, the median or quartile values of the number of days meeting prescription are useful in establishing target burn acreages. Knowing in what part of the season burning days are most likely to occur is useful middle to long range planning information. Seasonal scheduling of burning activities should be easier with this kind of prior information.

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Local fire managers can use previous years' fire weather observations (including data from the National Fire Weather Library) to estimate probabilities of future days' falling within burning and smoke dispersal prescriptions. The computer programs can be used by field personnel from remote terminals via telephone service.

Keywords: Prescribed fire, fire use planning, climatology, computer program.

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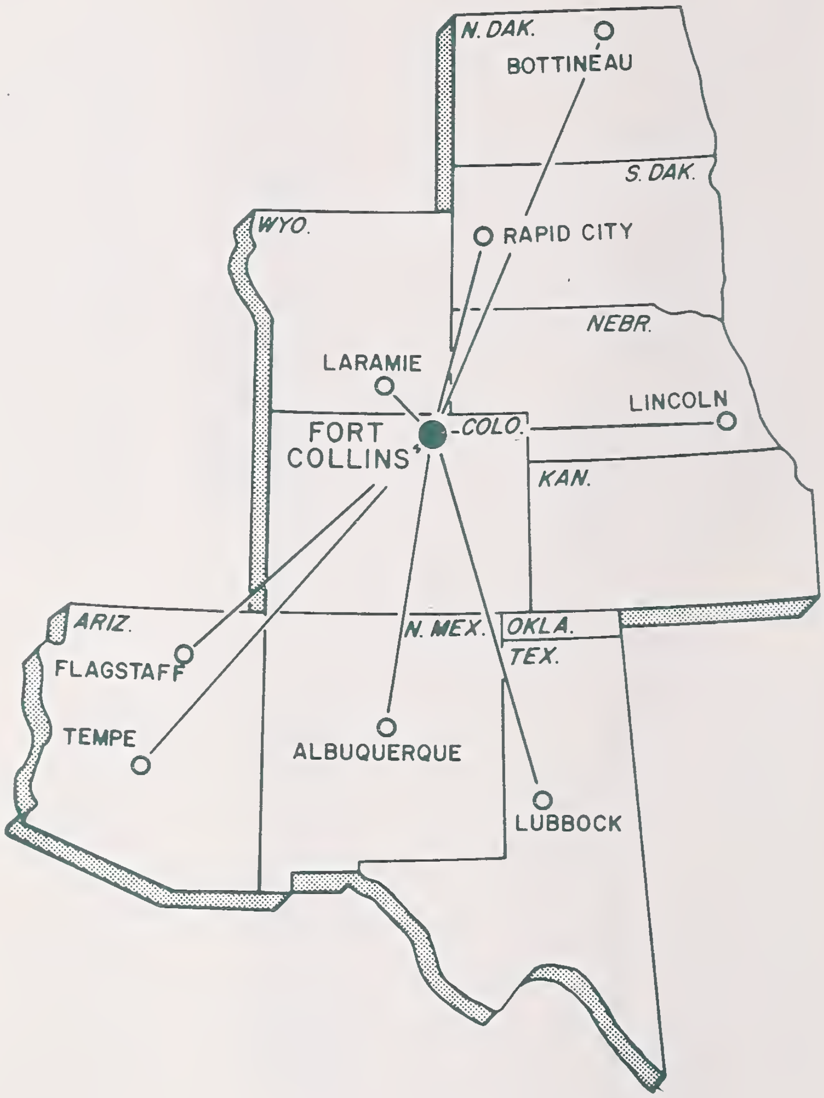
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